Newton's Law of Universal Gravitation

The formula $\mathbf{F_g = mg}$ is used to describe the *weight* of an object, in Newtons. Looking at the formula more closely, we see:

- The term 'weight' is also known as *force of gravity.*
- Like all forces, $\mathbf{F_g}$ depends on two objects:
  - our planet Earth, which exerts a *gravitational field strength* '**g**' all around it, in N/kg.
  - some other object, such as you, that is being pulled to Earth by its field strength.
- The field strength '**g**' is equal to 9.8 N/kg at or near Earth's surface, but is much weaker as you move away a significant distance from the surface.
- Other objects in space, like stars, planets and moons, each have their own gravitational field strengths '**g**' that may be stronger or weaker than that of Earth, depending on their mass and the distance away from them.

Although it may not seem so, '**g**' exists everywhere in space! Its value varies from one location to another, so that $\mathbf{F_g = mg}$ is not very useful for finding the force of gravity that exist between two objects.

Through experimental research, it was Isaac Newton who first determined how the force of gravity is affected in space:

- mass attracts mass, and the size of each mass directly affects the amount of attraction between them, so that $\mathbf{F \propto Mm}$
- the size of the force is inversely dependent on the square of the distance between the centers of mass of the two objects, so that:

$$\mathbf{F \propto \frac{1}{R^2}}$$

- from graphical analysis, an equation was established, with the slope being the universal constant '**G**', and the equation being

$$\boxed{\mathbf{F_g = G\frac{Mm}{R^2}}} \qquad \text{where} \qquad \mathbf{G = 6.67 \times 10^{-11}\ \frac{Nm^2}{kg^2}}$$

This new formula is useful, because it allows us not only to determine the force of attraction between two objects, but also calculate weight on other planets, or at great altitudes above Earth, where '**g**' is *not* 9.8 N/kg.

Example 1: Determine the force of attraction between a 35 kg dog and a 7.6 kg cat, watching each other from a distance of 4.8 m. (7.7×10^{-10} N)

(see Gravitation Ex 1 for answer)

Example 2:

(a) **Find the weight of a 50 kg person on Earth, using $F_g = mg$.**

(b) **Find the same weight on Earth, using $F_g = G\frac{Mm}{R^2}$.**

(c) **Find the weight of this person at an altitude of 170 km.**

(see Gravitation Ex 2 for answer)

Consider the answers to Example 2: why is this weight less than at Earth's surface? Because the gravitational field strength of the Earth is weaker as you move further away from its center of mass.